PHYSICS INVESTIGATORY PROJECT ON

ACOUSTICS OF INDIAN STRING INSTRUMENT: THE TANPURA

Submitted By
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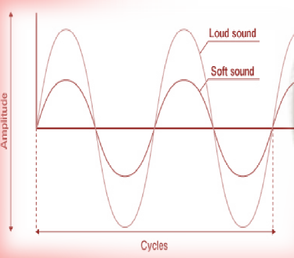

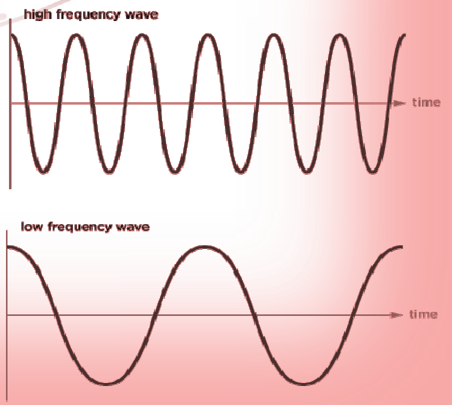

Understanding Mechanisms Underlying the Working of the String Instrument i.e. Tanpura and in turn Studying the Fundamental Principles of Frequential Acoustics

Thesis submitted for practical evaluation in AISSCE 2018-2019 in physics

Srijon Sadhukhan, XII B
Roll: ……………..
Kendriya Vidyalaya Mankhurd
2018-2019

तत् त्वं पूषन् अपावृणु
केन्द्रीय विद्यालय संगठन

DEPARTMENT OF PHYSICS
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CERTIFICATE

This is to certify that SRIJON SADHUKHAN, a student of class XII B, has successfully completed the research on the below mentioned project under the guidance of Mrs. PROMODINI PAL (subject teacher) during the year 2018-2019 in partial fulfillment of physics practical examination conducted by AISSCE, New Delhi.

Signature of the external examiner Signature of the physics teacher

ACKNOWLEDGEMENT

I wish to express my deep gratitude and sincere thanks to the Principal, Mrs. Indra Devi Jain of K.V. Mankhurd, for her encouragement and for all the facilities that she provided for this project work. I sincerely appreciate her magnanimity by taking me into her fold for which I shall remain indebted to.

I extend my hearty thanks to Mrs. Promodini Pal, physics teacher, who guided me to the successful completion of this project. I take this opportunity to express my deep sense of gratitude for her invaluable guidance, constant encouragement, immense motivation, which has sustained my efforts at all the stages of this Project work.

I can’t forget to offer my sincere thanks to parents and also to my classmates who helped me to carry out this project work successfully and for their valuable advice and support, which I received from them time to time.

Srijon Sadhukhan

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“Acoustics is the branch of physics that deals with the study of all mechanical waves in gases, liquids, and solids including topics such as vibration, sound, ultrasound and infrasound.”

1. ACOUSTICS

1.1 Introduction: Acoustics as a Subject of Physics

Hearing is one of the most crucial means of survival in the animal world, and speech is one of the most distinctive characteristics of human development and culture. Accordingly, the science of acoustics spreads across many facets of human society—music, medicine, architecture, industrial production, warfare and more. Likewise, animal species such as songbirds and frogs use sound and hearing as a key element of mating rituals or marking territories. Art, craft, science and technology have provoked one another to advance the whole, as in many other fields of knowledge. Robert Bruce Lindsay's 'Wheel of Acoustics' is a well accepted overview of the various fields in acoustics.

The word "acoustic" is derived from the Greek word *ἀκουστικός* (*akoustikos*), meaning "of or for hearing, ready to hear" and that from *ἀκουστός* (*akoustos*), "heard, audible", which in turn derives from the verb *ἀκούω* (*akouo*), "I hear".

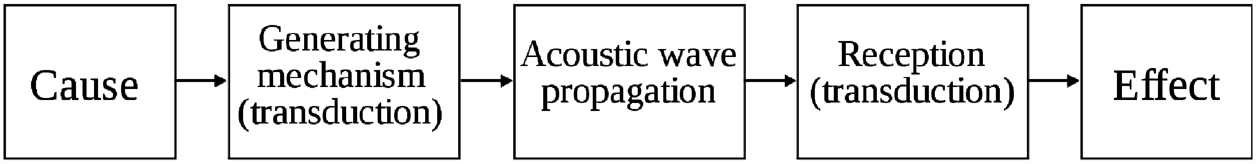
A scientist who works in the field of acoustics is an acoustician while someone working in the field of acoustics technology may be called an acoustical engineer. An acoustician is an expert in the science of sound. The application of acoustics is present in almost all aspects of modern society with the most obvious being the audio and noise control industries.

1.2 Fundamental Concepts of Acoustics

Definition

Acoustics is defined by ANSI/ASA S1.1-2013 as "(a) Science of sound, including its production, transmission, and effects, including biological and psychological effects. (b) Those qualities of a room that, together, determine its character with respect to auditory effects."

The study of acoustics revolves around the generation, propagation and reception of mechanical waves and vibrations.


Cause
Generating mechanism (transduction)
Acoustic wave propagation
Reception (transduction)
Effect

The steps shown in the above diagram can be found in any acoustical event or process. There are many kinds of cause, both natural and volitional. There are many kinds of transduction process that convert energy from some other form into sonic energy, producing a sound wave. There is one fundamental equation that describes sound wave propagation, the acoustic wave equation, but the phenomena that emerge from it are varied and often complex. The wave carries energy throughout the propagating medium. Eventually this energy is transduced again into other forms, in ways that again may be natural and/or volitionally contrived. The final effect may be purely physical or it may reach far into the biological or volitional domains. The five basic steps are found equally well whether we are talking about an earthquake, a submarine using sonar to locate its foe, or a band playing in a rock concert.

The central stage in the acoustical process is wave propagation. This falls within the domain of physical acoustics. In fluids, sound propagates primarily as a pressure wave. In solids, mechanical waves can take many forms including longitudinal waves, transverse waves and surface waves.

Acoustics looks first at the pressure levels and frequencies in the sound wave and how the wave interacts with the environment. This interaction can be described as either a diffraction, interference or a reflection or a mix of the three. If several media are present, a refraction can also occur. Transduction processes are also of special importance to acoustics.

Wave Propagation: Pressure Levels

In fluids such as air and water, sound waves propagate as disturbances in the ambient pressure level. While this disturbance is usually small, it is still noticeable to the human ear. The smallest sound that a person can hear, known as the threshold of hearing, is nine orders of magnitude smaller than the ambient pressure. The loudness of these disturbances is related to the sound pressure level (SPL) which is measured on a logarithmic scale in decibels.

Wave Propagation: Frequency

Physicists and acoustic engineers tend to discuss sound pressure levels in terms of frequencies, partly because this is how our ears interpret sound. What we experience as "higher pitched" or "lower pitched" sounds are pressure vibrations having a higher or lower number of cycles per second. In a common technique of acoustic measurement, acoustic signals are sampled in time, and then presented in more meaningful forms such as octave bands or time frequency plots. Both of these popular methods are used to analyze sound and better understand the acoustic phenomenon.

The entire spectrum can be divided into three sections: audio, ultrasonic, and infrasonic. The audio range falls between 20 Hz and 20,000 Hz. This range is important because its frequencies can be detected by the human ear. This range has a number of applications, including speech communication and music. The ultrasonic range refers to the very high frequencies: 20,000 Hz and higher. This range has shorter wavelengths which allow better resolution in imaging technologies. Medical applications such as ultrasonography and elastography rely on the ultrasonic frequency range. On the other end of the spectrum, the lowest frequencies are known as the infrasonic range. These frequencies can be used to study geological phenomena such as earthquakes.

Analytic instruments such as the spectrum analyzer facilitate visualization and measurement of acoustic signals and their properties. The spectrogram produced by such an instrument is a graphical display of the time varying pressure level and frequency profiles which give a specific acoustic signal its defining character.

1.3 Musical Acoustics

Musical acoustics or **music acoustics** is a branch of acoustics concerned with researching and describing the physics of music – how sounds are employed to make music.

Examples of areas of study are the function of musical instruments, the human voice (the physics of speech and singing), computer analysis of melody, and in the clinical use of music in music therapy.

Physical Aspects

Whenever two different pitches are played at the same time, their sound waves interact with each other – the highs and lows in the air pressure reinforce each other to produce a different sound wave. Any repeating sound wave that is not a sine wave can be modeled by many different sine waves of the appropriate frequencies and amplitudes (a frequency spectrum). In humans the hearing apparatus (composed of the ears and brain) can usually isolate these tones and hear them distinctly.

When two or more tones are played at once, a variation of air pressure at the ear "contains" the pitches of each, and the ear and/or brain isolate and decode them into distinct tones.

When the original sound sources are perfectly periodic, the note consists of several related sine waves (which mathematically add to each other) called the fundamental and the harmonics, partials, or overtones. The sounds have harmonic frequency spectra. The lowest frequency present is the fundamental, and is the frequency at which the entire wave vibrates. The overtones vibrate faster than the fundamental, but must vibrate at integer multiples of the fundamental frequency for the total wave to be exactly the same each cycle. Real instruments are close to periodic, but the frequencies of the overtones are slightly imperfect, so the shape of the wave changes slightly over time.

Subjective Aspects

Variations in air pressure against the ear drum, and the subsequent physical and neurological processing and interpretation, give rise to the subjective experience called sound. Most sound that people recognize as musical is dominated by periodic or regular vibrations rather than non-periodic ones; that is, musical sounds typically have a definite pitch). The transmission of these variations through air is via a sound wave. In a very simple case, the sound of a sine wave, which is considered the most basic model of a sound waveform, causes the air pressure to increase and decrease in a regular fashion, and is heard as a very pure tone. Pure tones can be produced by tuning forks or whistling. The rate at which the air pressure oscillates is the frequency of the tone, which is measured in oscillations per second, called hertz. Frequency is the primary determinant of the perceived pitch. Frequency of musical instruments can change with altitude due to changes in air pressure.

Harmonics, partials, and overtones

The fundamental is the frequency at which the entire wave vibrates. Overtones are other sinusoidal components present at frequencies above the fundamental. All of the frequency components that make up the total waveform, including the fundamental and the overtones, are called partials. Together they form the harmonic series.

Overtones that are perfect integer multiples of the fundamental are called harmonics. When an overtone is near to being harmonic, but not exact, it is sometimes called a harmonic partial, although they are often referred to simply as harmonics. Sometimes overtones are created that are not anywhere near a harmonic, and are just called partials or inharmonic overtones.

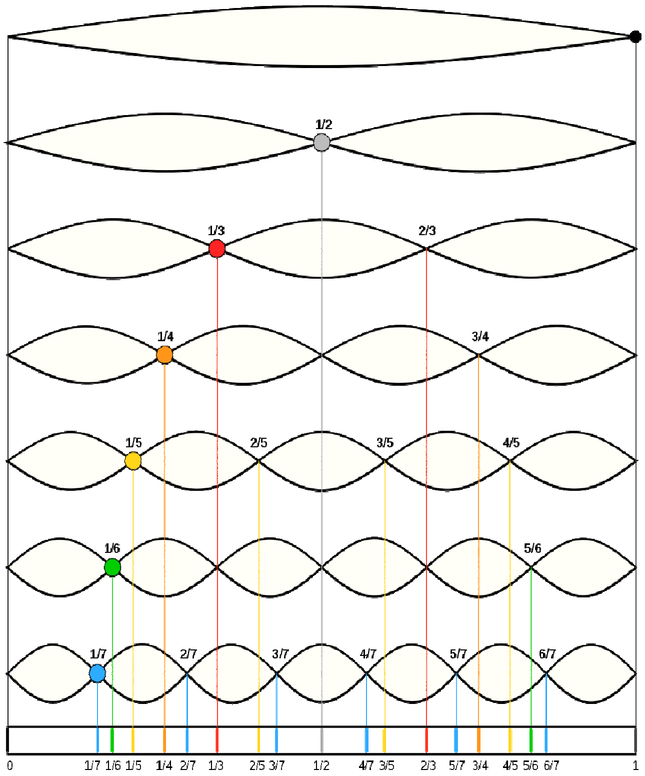


Figure 1.1: *Scale of Harmonics*

The fundamental frequency is considered the *first harmonic* and the *first partial.* The numbering of the partials and harmonics is then usually the same; the second partial is the second harmonic, etc. But if there are inharmonic partials, the numbering no longer coincides. Overtones are numbered as they appear *above* the fundamental. So strictly speaking, the *first* overtone is the *second* partial (and usually the *second* harmonic). As this can result in confusion, only harmonics are usually referred to by their numbers, and overtones and partials are described by their relationships to those harmonics.

Harmonics and non-linearities

When a periodic wave is composed of a fundamental and only odd harmonics (f, 3f, 5f, 7f …), the summed wave is *half-wave symmetric*; it can be inverted and phase shifted and be exactly the same. If the wave has any even harmonics (0f, 2f, 4f, 6f …), it is asymmetrical; the top half is not a mirror image of the bottom.

Conversely, a system that changes the shape of the wave (beyond simple scaling or shifting) creates additional harmonics (harmonic distortion). This is called a *non-linear system*. If it affects the wave symmetrically, the harmonics produced are all odd. If it affects the harmonics asymmetrically, at least one even harmonic is produced (and probably also odd harmonics).

Harmony

If two notes are simultaneously played, with frequency ratios that are simple fractions (e.g. 2/1, 3/2 or 5/4), the composite wave is still periodic, with a short period—and the combination sounds consonant. For instance, a note vibrating at 200 Hz and a add together to make a wave that repeats at 100 Hz: every 1/100 of a second, the 300 Hz wave repeats three times and the 200 Hz wave repeats twice. Note that the total

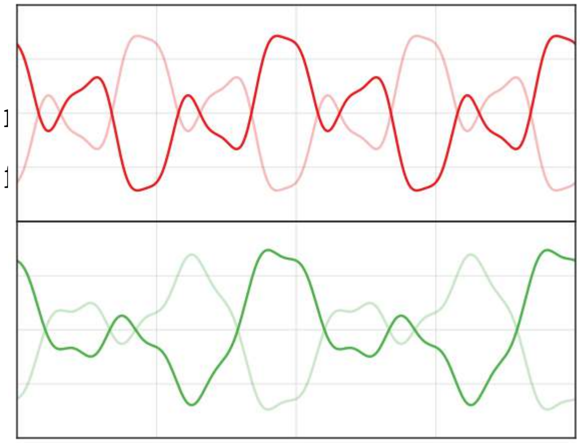


Figure 1.2: *A symmetric and asymmetric waveform. The red (upper) wave contains only the fundamental and odd harmonics; the green (lower) wave contains the fundamental and even harmonics.*

wave repeats at 100 Hz, but there is no actual 100 Hz sinusoidal component.

Additionally, the two notes have many of the same partials. For instance, a note with a fundamental frequency of 200 Hz has harmonics at: :(200,) 400, 600, 800, 1000, 1200, …

A note with fundamental frequency of 300 Hz has harmonics at: :(300,) 600, 900, 1200, 1500, … The two notes share harmonics at 600 and 1200 Hz, and more coincide further up the series.

The combination of composite waves with short fundamental frequencies and shared or closely related partials is what causes the sensation of harmony. When two frequencies are near to a simple fraction, but not exact, the composite wave cycles slowly enough to hear the cancellation of the waves as a steady pulsing instead of a tone. This is called beating, and is considered unpleasant, or dissonant.

The frequency of beating is calculated as the difference between the frequencies of the two notes. For the example above, |200 Hz - 300 Hz| = 100 Hz. As another example, a combination of 3425 Hz and 3426 Hz would beat once per second (|3425 Hz - 3426 Hz| = 1 Hz). This follows from modulation theory.

The difference between consonance and dissonance is not clearly defined, but the higher the beat frequency, the more likely the interval is dissonant. Helmholtz proposed that maximum dissonance would arise between two pure tones when the beat rate is roughly 35 Hz.

Scales

The material of a musical composition is usually taken from a collection of pitches known as a scale. Because most people cannot adequately determine absolute frequencies, the identity of a scale lies in the ratios of frequencies between its tones (known as intervals).

The diatonic scale appears in writing throughout history, consisting of seven tones in each octave. In just intonation the diatonic scale may be easily constructed using the three simplest intervals within the octave, the perfect fifth (3/2), perfect fourth (4/3), and the major third (5/4). As forms of the fifth and third are naturally present in the overtone series of harmonic resonators, this is a very simple process.

The following table shows the ratios between the frequencies of all the notes of the just major scale and the fixed frequency of the first note of the scale.

C	**D**	**E**	**F**	**G**	**A**	**B**	**C**
1	9/8	5/4	4/3	3/2	5/3	15/8	2

There are other scales available through just intonation, for example the minor scale. Scales that do not adhere to just intonation, and instead have their intervals adjusted to meet other needs are called *temperaments*, of which equal temperament is the most used. Temperaments, though they obscure the acoustical purity of just intervals, often have desirable properties, such as a closed circle of fifths.

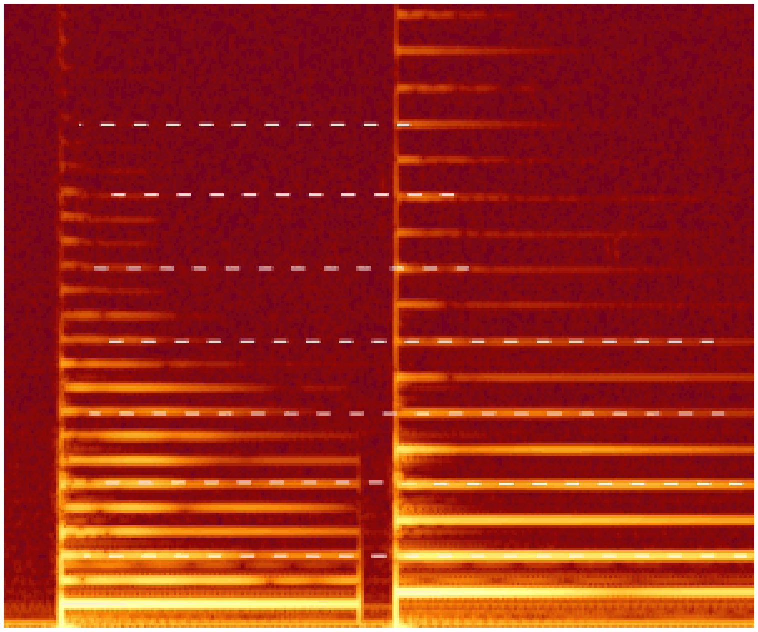


Figure 1.3: *A spectrogram of a violin playing a note and then a perfect fifth above it. The shared partials are highlighted by the white dashes.*

“In string theory, all particles are vibrations on a tiny rubber band; physics is the harmonies on the string; chemistry is the melodies we play on vibrating strings; the universe is a symphony of strings, and the 'Mind of God' is cosmic music resonating in 11-dimensional hyperspace.”

-Michio Kaku

2. TANPURA

2.1 Tanpura: A String Instrument

The **tanpura** is a long-necked plucked string instrument, originating from the Indian subcontinent, found in various forms in Indian music. It does not play melody but rather supports and sustains the melody of another instrument or singer by providing a continuous harmonic bourdon or drone. A tanpura is not played in rhythm with the soloist or percussionist: as the precise timing of plucking a cycle of four strings in a continuous loop is a determinant factor in the resultant sound, it is played unchangingly during the complete performance. The repeated cycle of plucking all strings creates the sonic canvas on which the melody of the raga is drawn. The combined sound of all strings, each string a fundamental tone with its own spectrum of overtones, is a rich and vibrant, dynamic-yet-static tone-conglomerate, due to interactive harmonic resonances that will support and blend with the external tones sung or played by the soloist.

The name of the instrument derives from Persian tanbūr where it designates a group of long necked lutes. Hindustani musicians favour the term 'tanpura' whereas Carnatic musicians say 'tambura'; 'tanpuri' is a smaller variant sometimes used for accompanying instrumental soloists.

2.2 Construction of the Tanpura

The Tanpura is basically made up of two parts; a long wooden part called neck is attached with a hard round oval-sphered structure made up of dried pumpkin. This whole dried pumpkin will work as the soundbox, and the part in which the soundbox is incorporated is called the body. The soundbox inside acts as a resonator which helps in amplifying the sound. The body and neck are joined in the position called heel.

A **nut**, on a stringed musical instrument, is a small piece of hard material that supports the strings at the end closest to the headstock or scroll. The nut marks one end of the vibrating length of each open string, sets the spacing of the strings across the neck, and usually holds the strings at the proper height from the fingerboard. Along with the bridge, the nut defines the vibrating lengths (scale lengths) of the open strings.

The main function of a headstock is to house the pegs or mechanism that holds the strings at the "head" of the instrument.

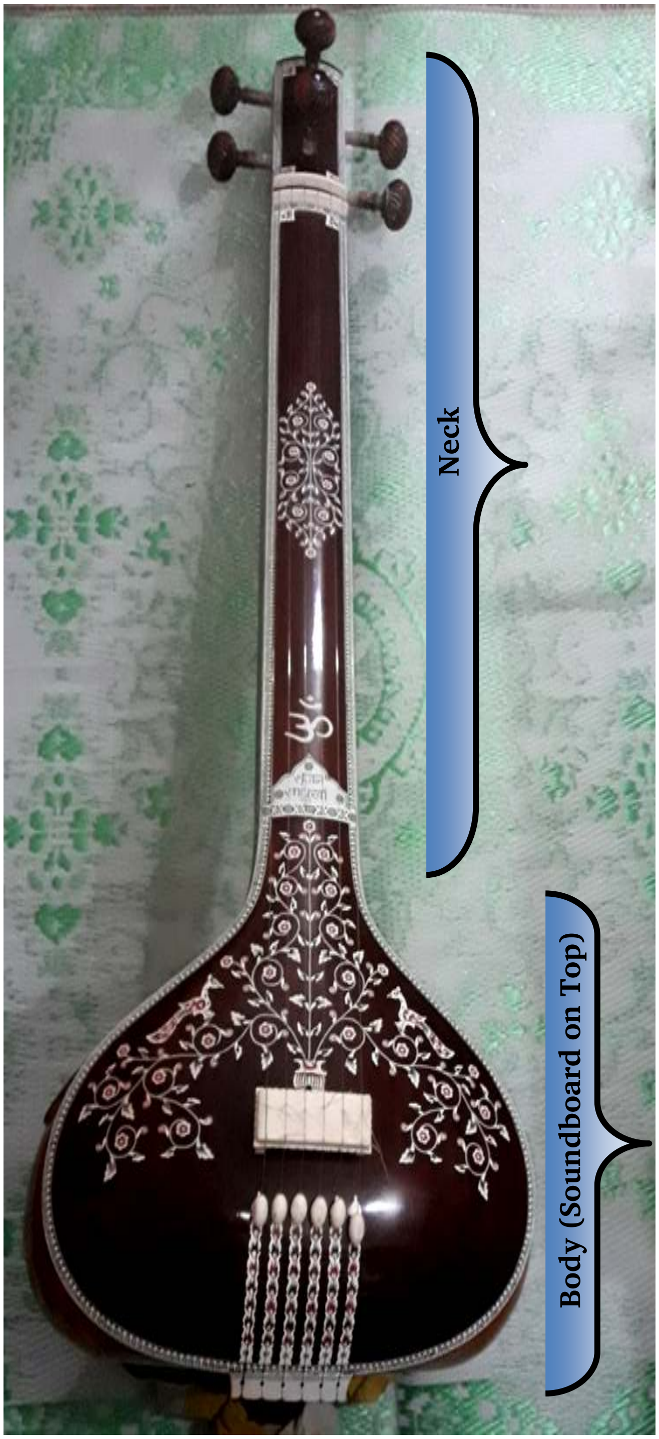


Figure 2.1: *A Male Tanpura of 6 strings*

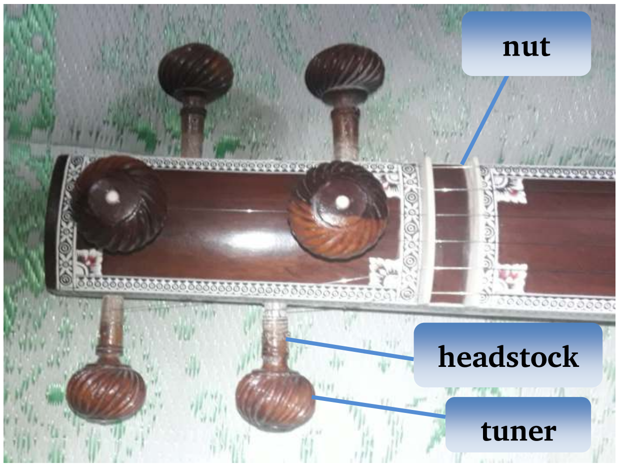


Figure 2.2: *The "head" of the Tanpura with six machine heads. The headstock (the thinner stick piece attached with the round-shaped tuner) is found attached with the machine head or the tuner. This headstock is found in the exterior of the structure, unlike in the guitar where it is found inserted into the head.*

A **machine head** (also referred to as a tuner or khunti) is a geared apparatus for tuning stringed musical instruments by adjusting string tension. Machine heads are usually located on the instrument's headstock. Machine heads on the headstock are commonly used to tune the instrument by adjusting the tension of strings and, consequentially, the pitch of sound they produce. Other names for tuners include pegs, gears, machines, cranks, knobs, tensioners, and tighteners.

The concept of wavelength and frequency intervenes here. Here, when we loosen the string of the tanpura, the length increases (i.e. wavelegth increases) which decreases the frequency, which lowers the pitch and results in a deep sound. When the string is tightened (or pulled upwards), it results the opposite.

A **bridge** is a device that supports the strings on a stringed musical instrument and transmits the vibration of those strings to another structural component of the instrument—typically a soundboard—which transfers the sound to the surrounding air. The saddle of a tanpura refers to the part of the bridge that physically supports the strings. The saddle's basic purpose is to provide the end point for the string's vibration at the correct location for proper intonation, and on acoustic guitars to transfer the vibrations through the bridge into the top wood of the tanpura. Saddles are typically made of plastic or bone for acoustic tanpura. The brige over the Tanpura is traditionally made up of animal bone. The bridge supports the strings and holds them over the body of the instrument under tension. At the "tail" of the instrument the strings are usually held by a tailpiece or bridge.

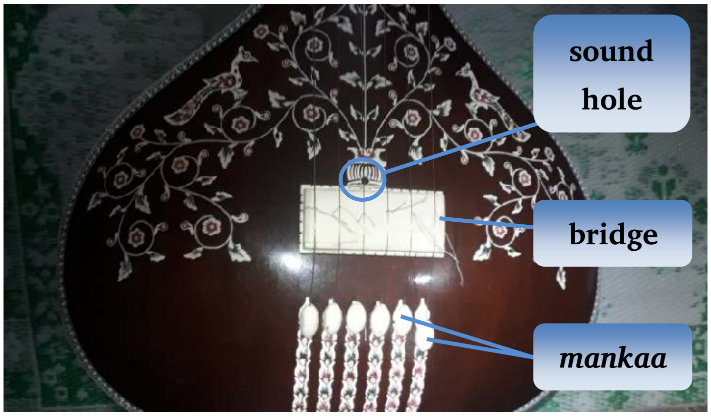


Figure 2.3: *The front of the Tanpura shows the soundboard in which a rectangular bone-piece called the bridge is attached at slightly down the middle. A small sound hole is visible at the middle. Six mankaas (shells) are placed below the bridge.*

The front part of the body is covered by wooden plate and is decorated by inlays. This is known as the soundboard. In case of Tanpura, it is united with the neck as one piece. A **sound board**, or **soundboard**, is the surface of a string instrument that the strings vibrate against, usually via some sort of bridge. The resonant properties of the sound board and the interior of the instrument greatly increase the loudness of the vibrating strings.

There are six *mankaas* (shells or cowries) placed over the soundboards in which are wreathed each of the strings, used for a more finer tuning.

There is a sound hole pierced into the soundboard, but it is very small, tiny as compared to sound holes in the guitars.

There are two types of Tanpura on the basis of number of strings, one is of 4 strings, and the latter is of 6 strings. Tanpuras are also classified on

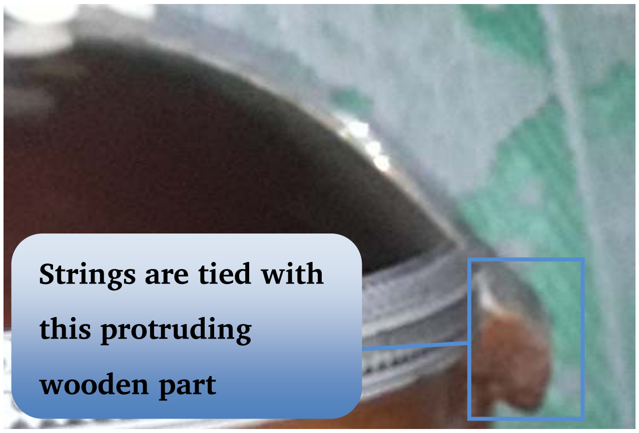


Figure 2.4: *The tail of the Tanpura*

the basis of the gender of the user (=vocalist), i.e. male and female. The male Tanpura is longer, and the strings had a more lenghtened vibrating part. The *more* lenghtened vibrating part was meant for the deepened nature of the male voice, where it represented longer wavelength to move to move to inversely produce shorter frequency ($\lambda \propto 1/\nu$) which means downward pitch. Similarly, the female Tanpura has a shortened length of vibrating part of string and produces high frequency and upward pitch.

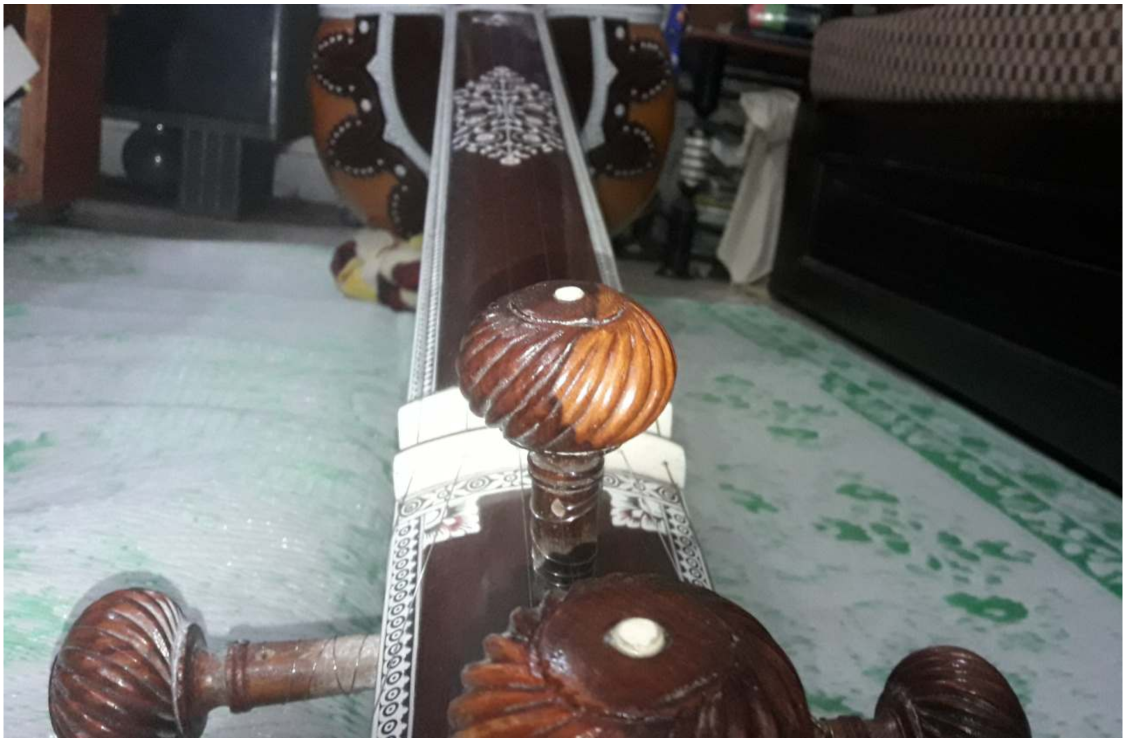


Figure 2.5: *A close picture of the head*

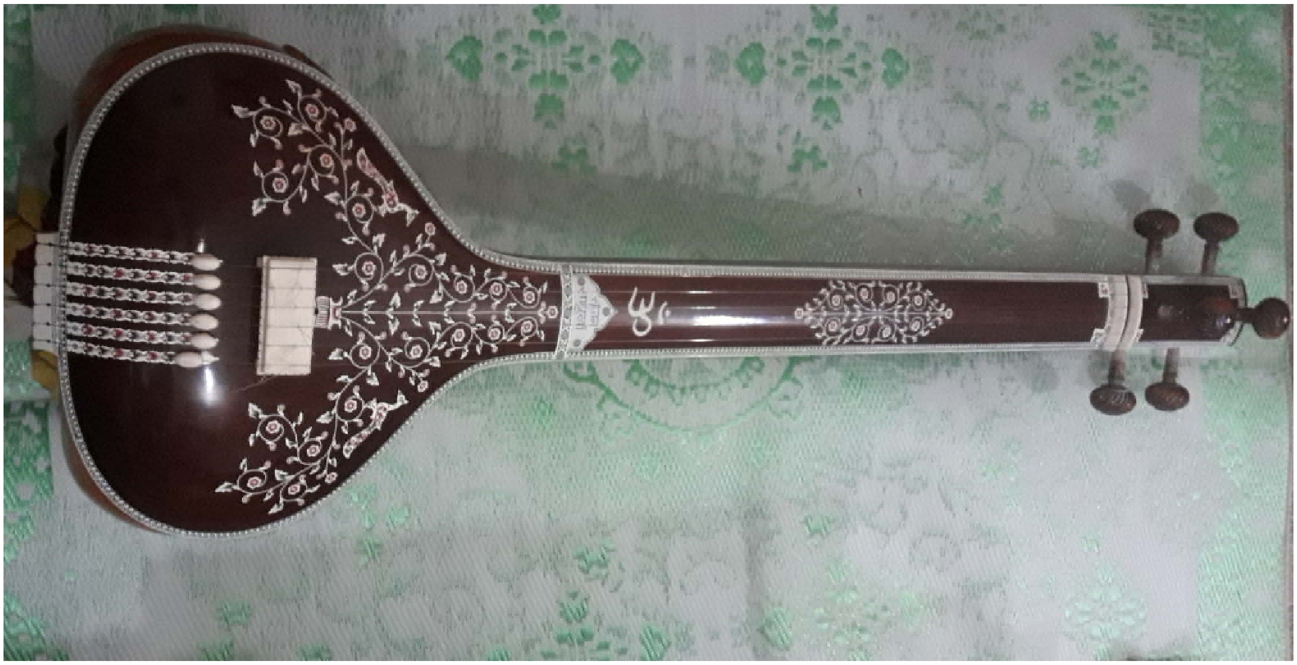


Figure 2.5: *A simple unlabelled picture of the sample Grand Tanpura*

2. TANPURA AND PHYSICS, EXPLAINED

3.1 Bridge and Strings and the Principle of Jivari

The overtone-rich sound and the audible movement in the inner resonances of tone is achieved by applying the principle of jivari which creates a sustained "buzzing" sound in which particular harmonics will resonate with focused clarity. Jiva refers to "soul", that which gives life, implying that the tanpura embodies an "animated" tone quality. To achieve this effect, the strings pass over a table-shaped, curved-top bridge, the front of which slopes gently away from the surface of the strings. When a string is plucked, it has an intermittent periodical grazing contact with the bridge. When the string moves up and down, the downward wave will touch a far point on the curve of the bridge, and as the energy of motion of the string gradually diminishes, these points of contact of the string on the bridge will gradually shift as well, being a compound function of amplitude, the curvature of the bridge, pitch, string tension and time. When the string is plucked, it has a large amplitude. As the energy of the string's movement gradually diminishes, the contact point of the string with the bridge slowly creeps up the slope of the bridge. Depending on scale, tension and pitch, this can take between three and ten seconds.

This dynamic process can be fine-tuned using a cotton thread between string and bridge: by shifting the thread, the grazing contact sequence is shifted to a different position on the bridge, changing the harmonic content (*see Fig. 2.3*). Every single string produces its own cascading range of harmonics and, at the same time, builds up a particular resonance. According to this principle, tanpuras are attentively tuned to achieve a particular tonal shade relative to the tonal characteristics of the raga. These more delicate aspects of tuning are directly related to what Indian musicians call raga svaroop, which is about how characteristic intonations are important defining aspects of a particular raga. The tanpura's particular setup, with the cotton thread as a variable focus-point, made it possible to explore a multitude of harmonic relations produced by the subtle harmonic interplay in time of its four strings.

3.2 The Jivari Phenomenon: Explained

Jivari in Indian classical music refers to the overtone-rich "buzzing" sound characteristic of classical Indian string instruments such as the Tanpura, Sitar, Surbahar, Rudra Veena and Sarasvati Veena. *Jivari* can refer to the acoustic phenomenon itself and to the meticulously carved bone; ivory or wooden bridges that support the strings on the sounding board and produce this particular effect.

Under the strings of tanpuras, which are unfretted (unstopped), and occasionally under those bass drone strings of sitars and surbahars which are seldom fretted, cotton threads are placed on the javari bridge to control the exact position of the node and its height above the curved surface, in order to more precisely refine the sound of javari. These cotton threads are known in Hindi as 'jīvā', meaning "life" and referring to the brighter tone heard from the plucked string once the thread has been slid into the correct position. This process is called "adjusting the javari". After a substantial time of playing, the surface directly under the string will wear out through the erosive impact of the strings. The sound will become thin and sharp and tuning also becomes a problem. Then a skilled, experienced craftsman needs to redress and polish the surface, which is called “doing the javari” (“Javārī Sāf Karnā” or “Cleaning the Javārī”).

The rich and very much 'alive' resonant sound requires great sensitivity and experience in the tuning process. In the actual tuning, the fundamentals are of lesser interest as attention is drawn to the sustained harmonics that should be clearly audible, particularly the octaves, fifths, major thirds and minor sevenths of the (fundamental) tone of the string. The actual tuning is done on three levels: firstly by means of the large pegs, secondly, by carefully shifting tuning-beads for micro-tuning and thirdly, on a tanpura, by even more careful shifting of the cotton threads that pass between the strings and the bridge, somewhat before the zenith of its curve.

3.2.1 Effect

Typical of *Javari* on an instrument with preferably long strings, is that on the soundboard the strings run over a wide bridge with a very flat parabolic curve. The curvature of the bridge has been made in a precise relation to the optimum level of playing, or more exact, a precise amplitude of each string. Any string, given length, density, pitch and tension, wants to be plucked within the limits of its elasticity, and so vibrate harmoniously with a steady pitch. When a string of a tanpura is plucked properly, it produces a tone with certain amplitude that will slowly decrease as the tone fades out. In this gradual process, the string, moving up and down according to its frequency, will make a periodic grazing contact with the curved surface of the bridge. The exact grazing-spot will gradually shift up the sloping surface, as a function of the decreasing amplitude, finally dissolving into the rest-position of the open string. In this complex dynamic sonation process, the shifting grazing will touch upon micro-nodes on the string, exciting a wide range of harmonics in a sweeping mode. The desired effect is that of a cascading row of harmonics in a rainbow of sound. *As an analogy, a properly shaped and adjusted Javari is similar to the refraction of white light through a prism.* When the prism is of good proportions and quality and used properly, the phenomenon should produce itself. "The voice of an artist which is marked by a rich sound resembling that produced by two consonants played together is often loosely known to have Javārī in it, although such use is arbitrary."

3.2.2 Construction

The Javari of a tanpura is in a way fine-tuned with a cotton thread under the string. Both the thread itself and its function are called 'jiva'. The jiva lifts the string by its diameter off the bridge and gives the necessary clearance and adjustability. By carefully shifting the jiva the sequence of the shifting grazing on the parabolic surface of the bridge becomes 'tuneable' within limits. For each string there should be a spot relative to the curve of the bridge where optimum sound quality is found. Within the area of optimum resonance and sustain, a little play should be available for further fine-tuning, in which the jiva can hardly be seen to move. Staying with optics, shifting the jiva would be similar to using the manual fine focus on a camera. Experienced 'javari-makers' will agree that the 'javari' has to be made specific to certain string lengths, gauges and pitches and certain amplitudes. The curvature of the bridge of the main strings of a sitar will be different from that of the smaller and lower bridge in front of the main bridge, which carries the sympathetic resonance-strings (tarafs). As this choir of thinner and shorter strings is excited solely by the sympathetic resonance with the tones played on the main strings, the general amplitude is smaller, so accordingly the curvature will be flatter. The making of a perfectly sounding *Javari* for any instrument requires a very high degree of skill and expertise. Tanpuras are the only instruments that are always used with jiva-threads, except the octave-tamburis. Sitar, Rudra Veena, Sarasvati Veena, all have parabolic wide Javari bridges for the main playing strings. Sarod and Sarangi have some of their sympathetic resonance strings (tarafs) on small, flat javari-bridges similar to that of the sitar. The javari of a sitar will be made according to the wishes of the player, either 'open' ('khula') with a bright sounding javari-effect, or 'closed' ('band') with a relatively more plain tone, or something in between ('ghol'). The choice depends on the preference of the sitar-player and on the adapted playing style.

4. CONCLUSION

It is to be noted that the instrument we discussed in this text material has an evolutionary connection with all other prominent string instruments in the world, where we can observe the structural similarity, or analogy at its best among the similar instruments like sitar, guitar etc. They all have a history of a large evolutionary period. However, to fully understand the working mechanism of the native instruments in India, we have to study them in scientific levels. People have to be educated and made aware about such things with scientific approach, and this also represents our ages long cultural relations with scientificity and fine traditional craftmanship.

Music, contrary to today's colloquial beliefs, too has connections with science, especially physical branches, which makes the subject of music worth studying. Music is considered in some religious sections of society as something malignant and leads to materialisticity. This principle should be challenged as to encourage logic among common masses.

Musicians; instrumentalists, vocalists and musical apparatus manufacturers and craftsmen alike should be encouraged to study scientific resources in various branches especially **mathematics**. It has also been observed that lack of mathematical skills make it unable for musicologists in performing applications in music, especially, beat-matching and calculations (in musical performances, sometimes very complicated to calculate) and understanding of various physical phenomena in music (from the relevant quote, “mathematics is the language of physics”).

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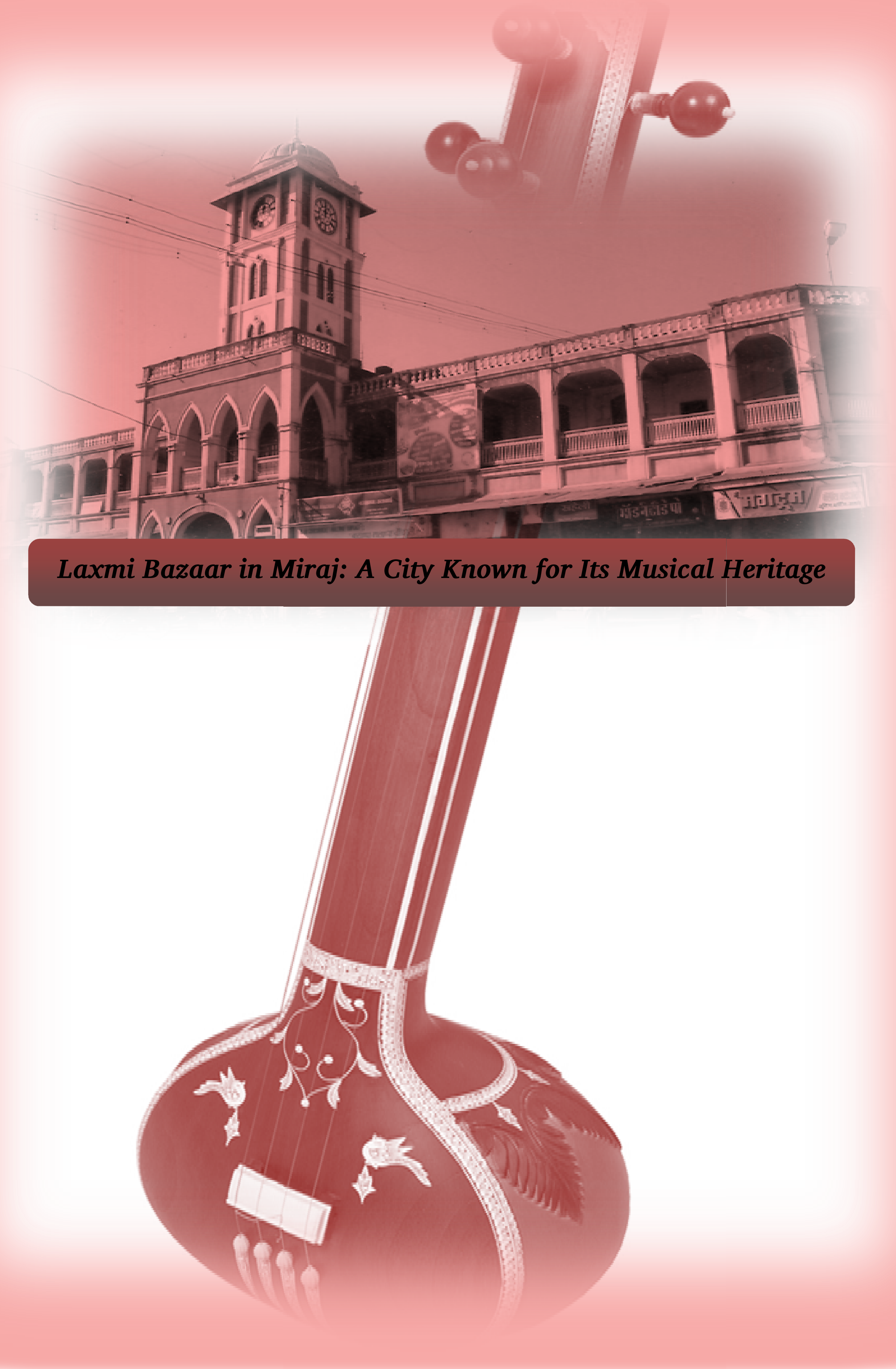

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